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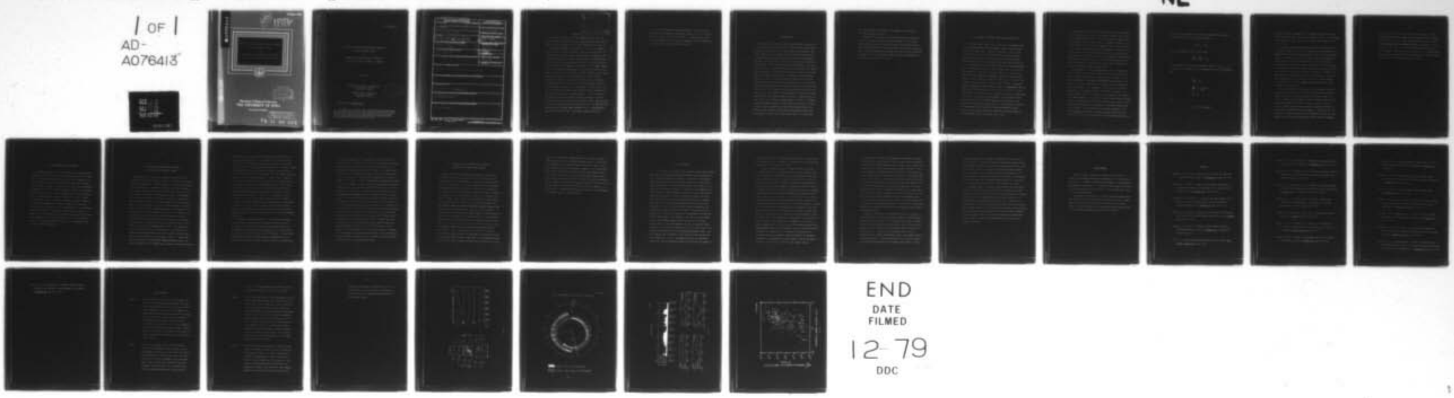

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A Correlation Between Auroral Kilometric Radiation and Field-Aligned Currents

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May, 1979

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ABSTRACT

Simultaneous observations of field-aligned currents (FAC) and auroral kilometric radiation (AKR) are compared from the polar orbiting satellites Triad and Hawkeye. The Triad observations were restricted to the evening-to-midnight local time sector (19 to 01 hours magnetic local time) in the northern hemisphere. This is the region where it is believed the most intense storms of AKR originate. The Hawkeye observations were restricted to when the satellite was in the AKR "emission cone" in the northern hemisphere and at radial distances $\geq 7\ R_E$ (earth radii) to avoid local propagation cutoff effects. A $(R/7\ R_E)^2$ normalization to the power flux measurements of the kilometric radiation from Hawkeye is used to take into account the radial dependence of this radiation and to scale all intensity measurements such that they are independent of Hawkeye's position in the emission cone. Integrated field-aligned current intensities from Triad are determined from the observed transverse magnetic field disturbances. Statistically, there is a good correlation between the AKR intensity and the integrated current sheet intensity of field-aligned currents. It is found that as the intensity of auroral kilometric radiation increases so does the integrated auroral zone current sheet intensity increase. Statistically, the linear correlation coefficient between the log of the AKR power flux and the log of the current sheet intensity is 0.57. During weak AKR bursts ($< 10^{-18}$ watts $m^{-2}Hz^{-1}$) Triad always observed weak FAC's

($<$ 0.4 A m^{-1}) and when Triad observed large FAC's ($\geq$ 0.6 A m^{-1}) the AKR intensity from Hawkeye was moderately intense (10^{-15} to 10^{-14} watts m^{-2}Hz^{-1}) to intense ($>10^{-14}$ watts m^{-2}Hz^{-1}). It appears that auroral zone field-aligned currents may play an important role in the generation or amplification of auroral kilometric radiation.

I. INTRODUCTION

From satellite observations, intense electromagnetic radiation at kilometric wavelengths has been found to escape outward from the Earth's auroral zone. This radiation has been called auroral kilometric radiation or AKR since a considerable amount of evidence indicates that it is generated by auroral particle precipitation during the geomagnetic substorms. Auroral kilometric radiation has been found by many authors [Dunckel et al., 1970; Gurnett, 1974; Kaiser and Alexander, 1977; and Voots et al., 1977] to be associated with the auroral electrojet current that flows parallel to the Earth at auroral zone latitudes in the ionosphere. But, what is really needed is to determine the relationship between the intensity of auroral kilometric radiation and the field-aligned currents (FAC) flowing along the geomagnetic field into and out of the auroral zone since auroral kilometric radiation has recently been correlated with fast streams of precipitating auroral electrons [Green et al., 1979b]. This relationship may be helpful in developing a better understanding of how auroral kilometric radiation is generated and the role it plays in the dynamics of magnetospheric substorms. In addition, if auroral kilometric radiation is correlated with auroral zone field-aligned currents an important link may be established between the Io enhanced Jovian decametric emissions and field-aligned currents which are believed to exist between Io and Jupiter since it is widely held that auroral kilometric radiation is the terrestrial counterpart to the Jovian decametric emissions.

The purpose of this paper is to show the relationship between the power flux of auroral kilometric radiation observed by the eccentric orbiting Hawkeye spacecraft and field-aligned currents deduced from the magnetometer measurements of the low altitude polar orbiting Triad spacecraft. The Triad magnetometer experiment has been described by Armstrong and Zmuda [1973], and the Hawkeye plasma and radio wave experiment has been described by Kurth et al. [1975].

II. OBSERVATION OF FIELD-ALIGNED CURRENTS FROM TRIAD

The field-aligned currents used in this study are determined from triaxial fluxgate magnetometer measurements taken by the Triad spacecraft over College, Alaska. Launched on September 2, 1972, into a circular polar orbit of 800 km altitude, Triad is gravity gradient stabilized, and thus, has a spin period of one revolution per orbit. Even today Triad is successfully transmitting data to ground stations.

The determination of field-aligned currents from Triad magnetometer data is illustrated in Figure 1. The right-hand side is a plot of the measured ambient field (B_M) for the three sensors A, B, and Z on the spacecraft minus a theoretical geomagnetic model field (B_T, IGRF 1965.0 updated to time of data) as a function of time for day 78 of 1975. The vertical axis for each panel on the right side of Figure 1 is plotted in units of gammas and covers a range of 1000γ. The magnetometer onboard Triad measures ambient magnetic fields to a resolution of 12γ. In the three panels on the right-hand side of Figure 1, deviations of B_M-B_T from 0γ are due to sources such as field-aligned currents, spacecraft bias fields, inaccuracies in the model field, and slow deviations of the spacecraft altitude from a nominal position. The principal oscillations of the pendulum-shaped Triad satellite have been identified, and a method has been recently developed to remove the associated variations in the magnetometer data [Gustafsson et al., 1979].

Field-aligned currents produce obvious deviations from a baseline formed by B_M-B_T as easily seen in the A panel of Figure 1 from 25820 to 25970 seconds universal time. Little or no deflection in B_M-B_T due to field-aligned currents is seen in the B or Z panels which aids in the identification of this source as an external current. The orientation of the current sheets with respect to the spacecraft is believed to be the reason that the deflection from the baseline of B_M-B_T was almost entirely seen in the A panel (see below). The magnetic perturbations in the A panel of Figure 1 from 25840 to 25870 seconds and from 25915 to 25940 seconds are due to two east-west current sheets flowing out of and into the auroral ionosphere, respectively.

The orientation of the three magnetometer sensors onboard Triad is illustrated on the left side of Figure 1. The A and B sensors are both horizontal with respect to the ground and are 90° apart. The B sensor is mounted 45° away from the spacecraft velocity vector (black arrow). The Z sensor completes the orthogonal coordinate system and points anti-parallel to the geomagnetic field vector at auroral zone latitudes in the northern hemisphere. When Triad is tracked by the College, Alaska station, the horizontal A sensor measures the component of the ambient magnetic field that points nearly along constant invariant latitude. Field-aligned current sheets oriented along constant invariant latitude would, therefore, produce magnetic disturbances predominately in the A sensor. This can easily be seen by applying Ampere's Law to a field-aligned current sheet. Using a coordinate system whose unit vectors ($\hat{X}$, $\hat{Y}$, $-\hat{Z}$) are in the direction of the Triad magnetometer sensors

(B, A, Z) a field-aligned current sheet of thickness dx and infinite length (in $\hat{Y}$ direction) has a current j_Z where

$$(\nabla \times B_c)_z = \mu_o j_z$$

and B_c is the magnetic field of the current.

$$\frac{\partial B_{cy}}{\partial x} - \frac{\partial B_{cx}}{\partial y} = \mu_o j_z$$

As illustrated on the right side of Figure 1 panel B, if $B_{cx} \simeq 0$, i.e., no deflection or perturbation to the geomagnetic field in the $\hat{X}$ direction then

$$\frac{\partial B_{cy}}{\partial x} = \mu_o j_z \quad ;$$

$$\int dB_{cy} = \mu_o \int j_z dx \quad ;$$

$$\Delta B = \mu_o J \quad ;$$

thus

$$J = 8 \times 10^{-4} (\Delta B) \text{ Amps/m}$$

where ΔB is measured in gammas and is the magnetic deflection from the baseline formed by $B_M - B_T$ in the A panel of Figure 1 and J is the integrated current across the sheet current. From Figure 1 panel A, $\Delta B = 343\gamma$ or $J = 0.27$ A/m.

Triad magnetometer measurements enabled Iijima and Potemra [1976] to determine a magnetic local time and invariant latitude summary of the large scale field-aligned currents flowing into and out of the ionosphere. Figure 2 illustrates the auroral zone current system during weakly disturbed times from Iijima and Potemra [1976]. Note that in Figure 2 field-aligned currents are observed at all magnetic local times and that the current sheets are oriented nearly along constant invariant latitude. In contrast, the intense auroral kilometric radiation is believed to be generated on the nightside between 19 and 01 hours magnetic local time (see crossed-hatched lines in Figure 2) and in the auroral zone near 70° invariant latitude [see for example Alexander and Kaiser, 1976; Gallagher and Gurnett, 1976].

Several characteristics distinguish the field-aligned currents in the Harang discontinuity sector (2000-2400 MLT) from those observed at other local times (see Iijima and Potemra [1978] and Rostoker et al. [1978]). During undisturbed periods, the field-aligned current flow is often characterized by three basic overlapping regions. Namely, a region of current flow away from the auroral ionosphere surrounded to the poleward and equatorward sides by regions of current flow into the ionosphere. During disturbed periods, for example substorms, the field-aligned currents are highly variable and develop complicated features.

Multiple current sheets develop in this sector and pairs of field-aligned currents appear at higher latitudes separated from the large-scale system to the south. These characteristics are closely related to the development of the westward electrojet in this sector. For the purposes of this study only the Triad measurements from 19 hours to 01 hour magnetic local time will be used since this is the region where the most intense kilometric radiation is generated and the most complicated pattern of field-aligned currents are found.

III. AKR OBSERVATIONS FROM HAWKEYE

The Hawkeye spacecraft provided observations of auroral kilometric radiation up to 46 hours per 52-hour orbit from launch on June 3, 1974, until it reentered the atmosphere on April 28, 1978. Hawkeye was in a highly eccentric earth orbit of about 89° inclination with an apogee radial distance of nearly 22 R_E (earth radii) in the northern hemisphere. The angular distribution of auroral kilometric radiation at 178 kHz was determined by Green et al. [1977] from Hawkeye electric field observations. The back shading in Figure 4 of Green et al. [1977], termed the AKR emission cone, is the region of magnetic latitude and magnetic local time where Hawkeye has the highest probability of observing auroral kilometric radiation if it is being generated. The simultaneous observations, used in this study are selected from the times when Hawkeye is in the AKR emission cone at radial distances ≥ 7 R_E (to avoid local propagation cutoff effects, see Green et al. [1977]) and when Triad is in the auroral oval from 19 hours to 01 hour magnetic local time in the northern hemisphere.

IV. A CORRELATION BETWEEN AURORAL KILOMETRIC RADIATION AND FIELD-ALIGNED CURRENTS

Between the period June, 1974, to August, 1975, there were 257 Triad auroral zone passes meeting the criterion outlined in the previous section while Hawkeye was in the AKR emission cone. Some typical simultaneous measurements from Hawkeye and Triad are illustrated in Figure 3. The top panel of Figure 3 shows electric field intensities in units of power flux at 178 kHz from the plasma wave instrument onboard Hawkeye. All the radio emission above the receiver noise level is attributed to auroral kilometric radiation. Simultaneous magnetic field observations made by the Triad spacecraft during four consecutive passes through the auroral zone in the northern hemisphere at about 23 hours magnetic local time are shown in the panels marked A, B, C, and D. The magnetic field measurements are from the A sensor onboard Triad and are plotted in terms of ΔB deviation from the baseline formed by $B_M - B_T$. The A panel illustrates that the Triad pass through the auroral zone shows little evidence of east-west field-aligned current sheets. The maximum deviation occurs at about 0816:30 UT with $\Delta B \simeq 43\gamma$. Simultaneously, the Hawkeye plasma wave experiment does not detect auroral kilometric radiation (see arrow labeled A in the top panel of Figure 3). Approximately ninety minutes later on the next pass through the auroral oval in the northern hemisphere the Triad magnetometer experiment revealed an extremely complicated system of east-west field-aligned current sheets which is a typical Triad observation in this magnetic local time sector (see Section II). The integrated current across the major current sheet (0957 to 0959 UT) of the Triad pass in the B panel is 0.52 Amps/m. Meanwhile, Hawkeye observed intense auroral kilometric radiation from its position in the emission cone of more than 10^{-16} watts/(m^2Hz) (see arrow labeled B in the top panel of Figure 3). Panels C and D of Figure 3 also indicate complex east-west current sheets in the auroral oval as seen in these perturbations in the geomagnetic field. In both cases intense bursts of auroral kilometric radiation are detected by the Hawkeye plasma wave experiment simultaneously as pointed to by the C and D arrows in the top panel of Figure 3. The integrated current intensity of the field-aligned current sheets at 1320 UT in panel D of Figure 3 is nearly 0.85 Amps/m while the AKR power flux, the largest observed for this time period, was greater than 10^{-14} watts/(m^2Hz). Figure 3 is consistent with the idea that intense auroral zone field-aligned currents are correlated with intense bursts of auroral kilometric radiation.

To provide a qualitative evaluation of the relationship between auroral kilometric radiation and field-aligned currents, Figure 4 is a scatter plot of simultaneous three-minute average AKR power flux measurements at 178 kHz versus the integrated current intensity across the largest current sheets observed on each Triad pass. A three minute average of the electric field measurements from Hawkeye takes into account any spin modulation effect and gives a power flux determination on a time scale comparable to the complete crossing of Triad across the auroral zone. To take into account the radial dependence of auroral kilometric radiation, a $(R/7\ R_E)^2$ normalization is applied to the average power flux measurements. The R variable is the distance from the satellite to the average source region of auroral kilometric radiation (2.5 R_E along a 70° invariant latitude magnetic field line at a magnetic local time of 23 hours in agreement with Gallagher and Gurnett [1979]). The triangles in Figure 4 are the times when auroral kilometric radiation was not detected by Hawkeye above the receiver's noise level and represent an upper limit. A correlation can be seen which is, as the AKR power flux increases so does the integrated current intensity increase. Statistically, the linear correlation coefficient of the log of the power flux versus the log of the integrated current intensity is 0.57. A random error analysis produces a probability of less than 10^{-7}% in obtaining the 0.57 correlation coefficient from an uncorrelated parent population, illustrating the level of confidence for this correlation. From Figure 4, when the AKR power flux was weak ($< 10^{-18}$ watts/(m^2Hz)) the integrated current intensity was less than 0.36 Amps/m while for integrated current intensities greater than 0.6 Amps/m the AKR power flux was moderately intense (10^{-15} to 10^{-14} watts(m^2Hz)) to very intense ($> 10^{-14}$ watts/(m^2Hz)). The correlation in Figure 4 indicates that field-aligned currents may play an important role in the generation of auroral kilometric radiation since the currents are always observed in the auroral zone when Hawkeye observes AKR.

V. POSSIBLE SOURCE OF SCATTER IN THE CORRELATION BETWEEN AKR AND FIELD-ALIGNED CURRENTS

Several sources of uncertainty and fluctuations could have contributed to the scatter in Figure 4 which we will presently discuss. A detailed study of the distribution of intensity in the AKR emission cone at 178 kHz by Green et al. [1979a] revealed that in a coordinate system with the average source region of AKR (used in this study) at the origin, bursts of auroral kilometric radiation uniformly illuminate the AKR emission cone to within much less than 10 db. Therefore, the scatter in Figure 4 due to the position of Hawkeye in the AKR emission cone is expected to be less than 10 db. Kaiser and Alexander [1977] found that the peak in the emission spectrum of auroral kilometric radiation decreases with increasing AE. Since the 178 kHz channel on Hawkeye is near the average spectral peak, changes in the peak frequency could produce an increase in the observed power flux. The enhancement at 178 kHz due to this effect could produce a maximum increase of less than 10 db. Probably the largest source of scatter in Figure 4 is due to using global (power flux) versus point (field-aligned currents) measurements. Triad on any given pass, cuts through the nighttime auroral oval at nearly constant local time and it is certain that Triad will not always observe the most intense part of the pre-midnight field-aligned current system. Hawkeye, however, from its position in the AKR emission cone observes an integrated power flux of auroral kilometric radiation from the entire evening active auroral region. Global versus point measurements could easily produce the scatter in Figure 4 since many intense bursts of auroral kilometric radiation ($> 10^{-16}$ watts/m^{2}Hz)) would then be associated with relatively small field-aligned currents (<0.3 A/m), but there are no cases of intense field-aligned currents (>0.6 A/m) associated with weak ($< 10^{-17}$ watts/(m^{2}Hz) auroral kilometric bursts. Despite the relatively low linear correlation coefficient (0.57) from the present discussion of the sources of scatter in Figure 4 it is obvious that the correlation between auroral kilometric and pre-midnight field-aligned currents is relatively good.

VI. DISCUSSION

It is important to speculate on the role which field-aligned currents might play in the generation and possible amplification of auroral kilometric radiation as suggested by Figure 4. One direct relationship is that field-aligned currents are probably bringing into the AKR source region the particles or current whose energy, at least in part, is converted into the kilometric radiation. Increases in the integrated current intensities of field-aligned currents may be due to progressively larger and larger particle fluxes at progressively higher velocities. Since Triad does not have a particle experiment onboard, the energies and fluxes of the actual precipitating magnetospheric particles and upgoing (out of the ionosphere) ionospheric particles making up the field-aligned currents observed are not known. There are only a few examples of the simultaneous observation of field-aligned currents and particle measurements in the literature. The basic result from these studies [see for example Casserly and Cloutier, 1975] is that the particle fluxes, in the energy range of the particle detectors flown, (typically 0.5 to $>$ 20 keV) usually account for only 20% or less of the inferred current deduced from the accompanying magnetometer data. This result implies that the majority of the current carriers are particles at low energies ($<$ 0.5 keV). The examples given in the literature, however, are usually preliminary and may not reflect the true nature of the current carriers in field-aligned current used in this study since the simultaneous currents and particle observations are not always from the magnetic local times 19 to 01 hours.

A recent study by Green et al. [1979b] indicates that auroral kilometric radiation is correlated with high velocity (energies from 1 to 18 keV) electron precipitations in the pre-midnight auroral zone known as inverted-V events. However, if the majority of the field-aligned currents observed by Triad are carried by low energy particles then the correlation between AKR and field-aligned currents as shown in Figure 4 may indicate more of an indirect relationship. For example, current instabilities producing low frequency wave turbulence such as electrostatic ion cyclotron waves or ion acoustic waves in the auroral zone have been postulated by Kindel and Kennel [1971]. Kintner et al. [1978] have observed intense electrostatic ion cyclotron waves (~ 25 mV/m at 115 Hz) with the S3-3 spacecraft near 20 hours magnetic local time at an altitude of over 6,000 kilometers in the auroral zone and found then to be consistent with the current driven model proposed by Kindel and Kennel [1971]. Ion heating due to electrostatic ion cyclotron turbulence has been shown theoretically by Palmadesso et al. [1974] to produce anomalous resistivity and, thus, field-aligned potential drops. Field-aligned potential drops or parallel electric fields are generally believed to be responsible for the formation and acceleration of inverted-V electron precipitation events which may be in some way be responsible for the generation or amplification of auroral kilometric radiation (see Green et al. [1979b]). Thus, Figure 4 may be illustrating that increasing field-aligned current intensity increases the growth of the electrostatic ion cyclotron waves enhancing anomalous resistivity which leads to parallel electric fields and the production of inverted-V events associated with auroral kilometric radiation. This is a rather idealized interpretation since the process of producing field-aligned potential drops from anomolous resistivity is not related simply to the current intensity. Double layers and electrostatic shocks, which also produce field-aligned potential drops can be established by a current above a certain threshold. However, the magnitude of the field-aligned potential drop (for inverted-V acceleration) in a double layer or electrostatic shock is determined not from the intensity of the current but from the external generator such as the magnetospheric tail (see for example the review by Goertz [1979]). From these general considerations of accelerating mechanisms it is clear that the relationship between auroral kilometric radiation with field-aligned currents may be extremely complicated.

There are, in addition to the quantitative results of Figure 4, qualitative features of auroral kilometric radiation and field-aligned currents which deserve mention. The conditions which lead to the generation of auroral kilometric radiation must be easily met since, when Hawkeye is in the AKR emission cone, auroral kilometric radiation is detected above the receiver noise level nearly 90% of the time. Similarly, Triad observes field-aligned currents as a permanent feature of the auroral zone. As easily seen in panels B, C, and D of Figure 3 either much structure exists in the separate current sheets or rapid temporal variations in field-aligned currents exist on a time scale of seconds or both. The question of whether field-aligned currents exhibit rapid temporal fluctuations or have fine structured current sheets within current sheets can not be discerned with the single Triad spacecraft. It is interesting to note, however, that one basic characteristic of auroral kilometric radiation is that rapid fluctuations in the intensity of this radiation, like field-aligned currents, exists on a time scale of seconds and even less than a second (see Gurnett et al. [1979]).

In summary, Figure 4 illustrates quantitatively that field-aligned currents in the pre-midnight auroral zone are correlated with auroral kilometric radiation such that as the log of the AKR power flux increases so does the log of the integrated current intensity increase. It is suggested that field-aligned currents play not only a direct role in the generation of AKR but possibly also an indirect one with the development of parallel electric fields that produce inverted-V electron precipitation which has also been associated with auroral kilometric radiation. It is clear that the exact relationship between AKR and field-aligned auroral currents is far from being understood and that much work is needed in this area.

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REFERENCES

Alexander, J. K., and M. L. Kaiser, Terrestrial kilometric radiation 1. Spatial structure studies, J. Geophys. Res., 81, 5948, 1976.

Armstrong, J. C., and A. J. Zmuda, Triaxial magnetic measurements of field-aligned currents at 800 kilometers in the auroral region: Initial results, J. Geophys. Res., 78, 6802, 1973.

Casserly, R. T., Jr., and P. A. Cloutier, Rocket-based magnetic observations of auroral Birkeland currents in association with a structured auroral arc, J. Geophys. Res., 80, 2165, 1975.

Dunckel, N., B. Ficklin, L. Rorden, and R. A. Helliwell, Low-frequency noise observed in the distant magnetosphere with OGO 1, J. Geophys. Res., 75, 1854, 1970.

Gallagher, D. L., and D. A. Gurnett, Auroral kilometric radiation: Time-averaged source location, J. Geophys. Res., (accepted for publication), 1979.

Goertz, C. K., Double layers and electrostatic shocks in space, Rev. Geophys. Space Phys., 17, 48, 1979.

Green, J. L., D. A. Gurnett and S. D. Shawhan, The angular distribution of auroral kilometric radiation, J. Geophys. Res., 82, 1825, 1977.

Green, J. L., D. L. Gallagher, and D. A. Gurnett, The detailed intensity distribution of the auroral kilometric radiation emission cone (abstract), EOS, 60, 346, 1979a.

Green, J. L., D. A. Gurnett, and R. A. Hoffman, A correlation between auroral kilometric radiation and inverted-V electron precipitation, J. Geophys. Res., (accepted for publication), 1979b.

Gustafsson, G., T. A. Potemra, and N. A. Saflekos, Correction of variations in the TRIAD magnetic field data due to attitude uncertainties (abstract), EOS, 60, 348, 1979.

Gurnett, D. A., The Earth as a radio source: Terrestrial kilometric radiation, J. Geophys. Res., 79, 4227, 1974.

Gurnett, D. A., R. R. Anderson, F. L. Scarf, R. W. Fredricks, and E. J. Smith, Initial results from the ISEE-1 and -2 plasma wave investigation, Space Sci. Rev., 23, 103, 1979.

Iijima, T., and T. A. Potemra, Field-aligned currents in the dayside cusp observed by Triad, J. Geophys. Res., 81, 5971, 1976.

Iijima, T., and T. A. Potemra, Large-scale characteristics of field-aligned currents associated with substorms, J. Geophys. Res., 83, 599, 1978.

Kaiser, M. L., and J. K. Alexander, Relationship between auroral substorms and the occurrence of terrestrial kilometric radiation, J. Geophys. Res., 82, 5283, 1977.

Kindel, J. M., and C. F. Kennel, Topside current instabilities, J. Geophys. Res., 76, 3055, 1971.

Kintner, P. M., M. C. Kelley, and F. S. Mozer, Electrostatic hydrogen cyclotron waves near one earth radius altitude in the polar magnetosphere, Geophys. Res. Lett., 5, 139, 1978.

Kurth, W. S., M. M. Baumback, and D. A. Gurnett, Direction finding measurements of auroral kilometric radiation, J. Geophys. Res., 80, 2764, 1975.

Palmadesso, P. J., T. P. Coffey, S. L. Ossakow and K. Papadopoulos, Topside ionosphere ion heating due to electrostatic ion cyclotron turbulence, Geophys. Res. Lett., 1, 105, 1974.

Rostoker, G., J. C. Armstrong, and A. J. Zmuda, Field-aligned current flow associated with intrusion of the substorm-intensified westward electrojet into the evening sector, J. Geophys. Res., 80, 3571, 1975.

Voots, G. R., D. A. Gurnett and S. I. Akasofu, Auroral kilometric radiation as any indicator of auroral magnetic disturbances, _J. Geophys. Res._, _82_, 2259, 1977.

FIGURE CAPTIONS

Figure 1 The three panels (A, B, and Z) on the right-hand side are plots of the measured ambient magnetic field (B_M) from the triaxial sensors onboard Triad minus a theoretical geomagnetic field (B_T) in units of gammas. The large perturbation from the baseline formed by the B_M-B_T curve in the A panel is attributed to two east-west field-aligned current sheets. The left-hand side illustrates the orientation of the A, B, and Z magnetic field sensors onboard Triad during a pass over College, Alaska. The direction of the magnetic field sensors is used in determining the orientation of the auroral zone current sheets.

Figure 2 A polar plot in magnetic local time and invariant latitude of field-aligned currents observed by Triad during weakly disturbed times ($|AL| < 100\gamma$) from Iijima and Potemra [1976]. The crossed-hatched section from 19 hours to 01 hours is the magnetic local time region where the most intense bursts of AKR are believed to originate. Note, also that this is the region where the most complicated auroral zone current system is found. Only Triad magnetometer measurements inside the crossed-hatched region will be used in this study.

Figure 3 The top panel shows electric field measurements as a function of time from the Hawkeye satellite while it is in the AKR emission cone during four consecutive passes of the Triad spacecraft through the auroral oval in the northern hemisphere. The Triad magnetometer measurements from the A sensor plotted with respect to the baseline formed by $B_M - B_T$ are shown in the bottom panels A, B, C, and D. Note that when Triad observes large deflections in the magnetic field due to field-aligned currents Hawkeye observes intense kilometric radiation (times B, C, and D) but when little disturbances in the auroral zones are found, panel A, Hawkeye does not detect AKR above the receiver's threshold.

Figure 4 Simultaneous power flux measurements of AKR at 178 kHz versus the integrated current intensity of auroral zone field-aligned currents. A $(R/7\ R_E)^2$ normalization to the power flux measurements is applied to take into account the radial dependence of this radiation. The R variable is the distance from the satellite to the average source region of AKR (see text). The triangles represent an upper limit to the power flux since the kilometric radiation was not detected at those times. A correlation can be seen in that, as the power flux increases so does the integrated current intensity of field-aligned currents.

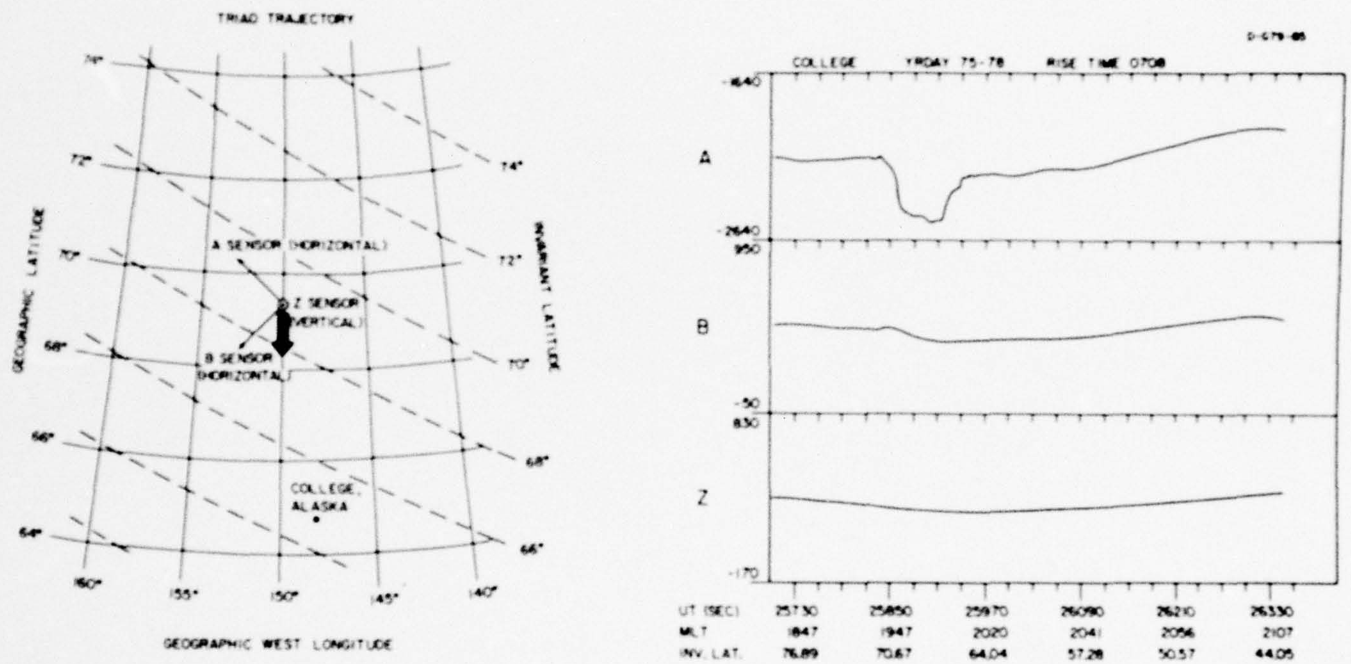

TRIAD TRAJECTORY
GEOGRAPHIC LATITUDE
INVARIANT LATITUDE
74°
72°
70°
68°
66°
64°
A SENSOR (HORIZONTAL)
Z SENSOR (VERTICAL)
B SENSOR (HORIZONTAL)
COLLEGE, ALASKA
160°
155°
150°
145°
140°
GEOGRAPHIC WEST LONGITUDE
D-679-86
COLLEGE
YRDAY 75-78
RISE TIME 0708
A
B
Z
-1640
-2640
950
-50
830
-170
UT (SEC) 25730 25850 25970 26090 26210 26330
MLT 1847 1947 2020 2041 2056 2107
INV. LAT. 76.89 70.67 64.04 57.28 50.57 44.05

Figure 1

C-G78-788

FAC'S DURING WEAKLY DISTURBED CONDITIONS

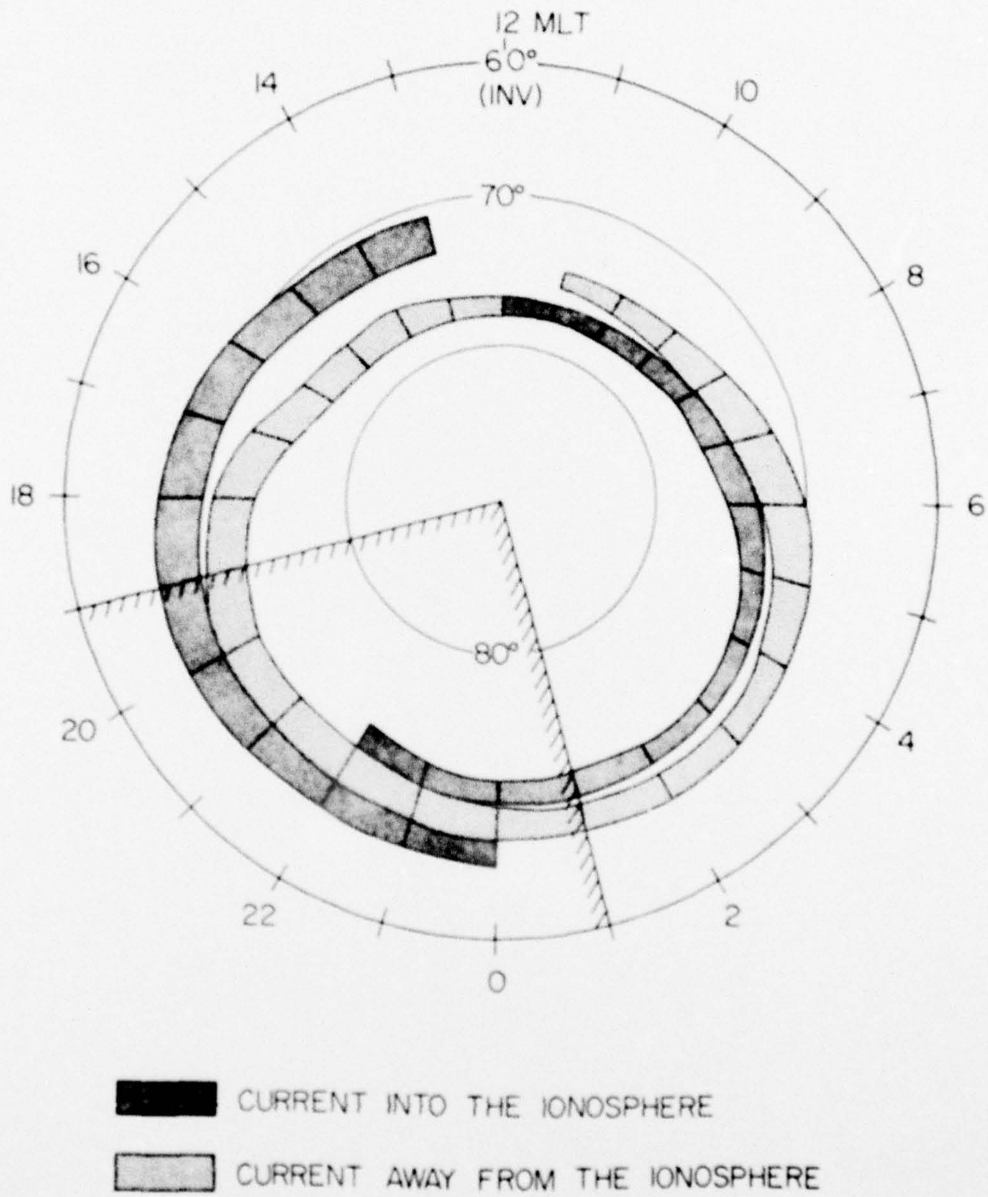


Figure 2

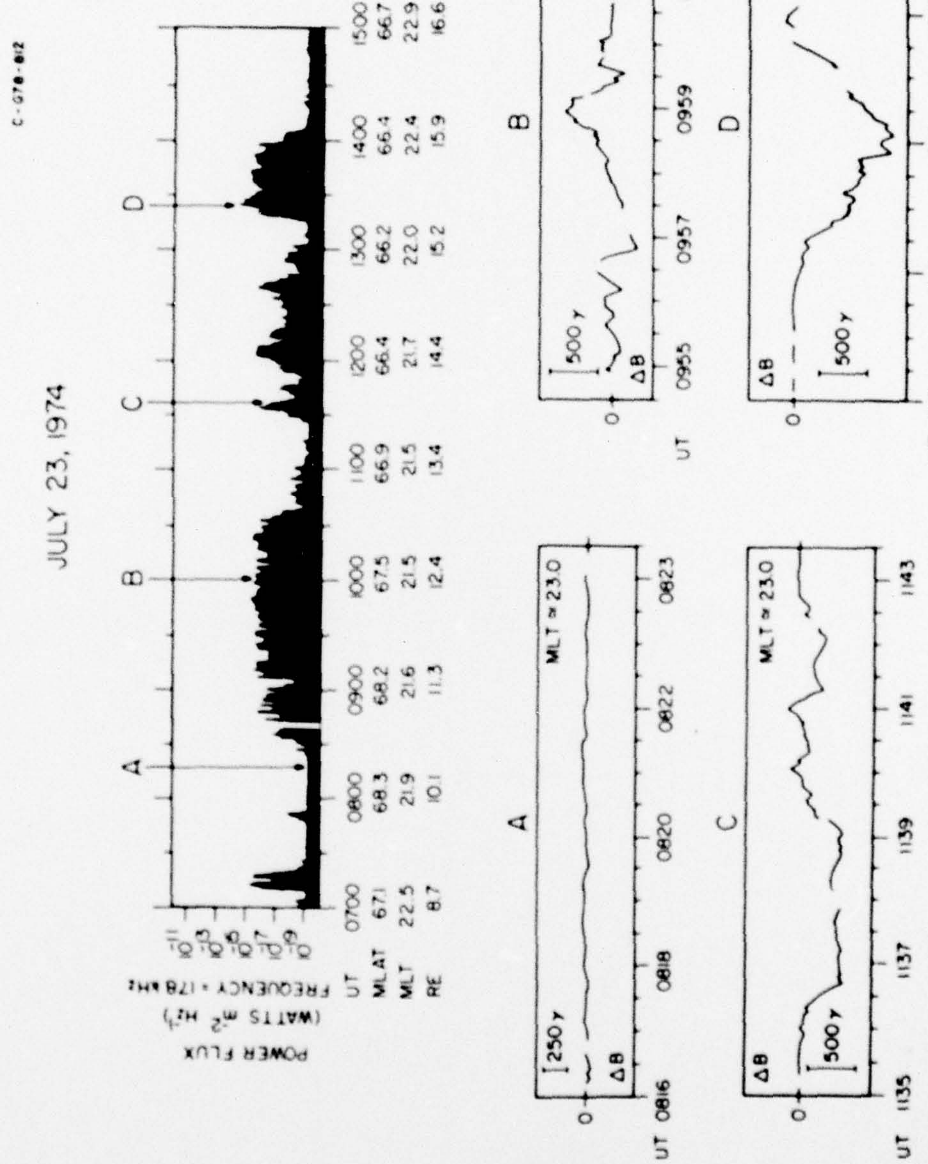
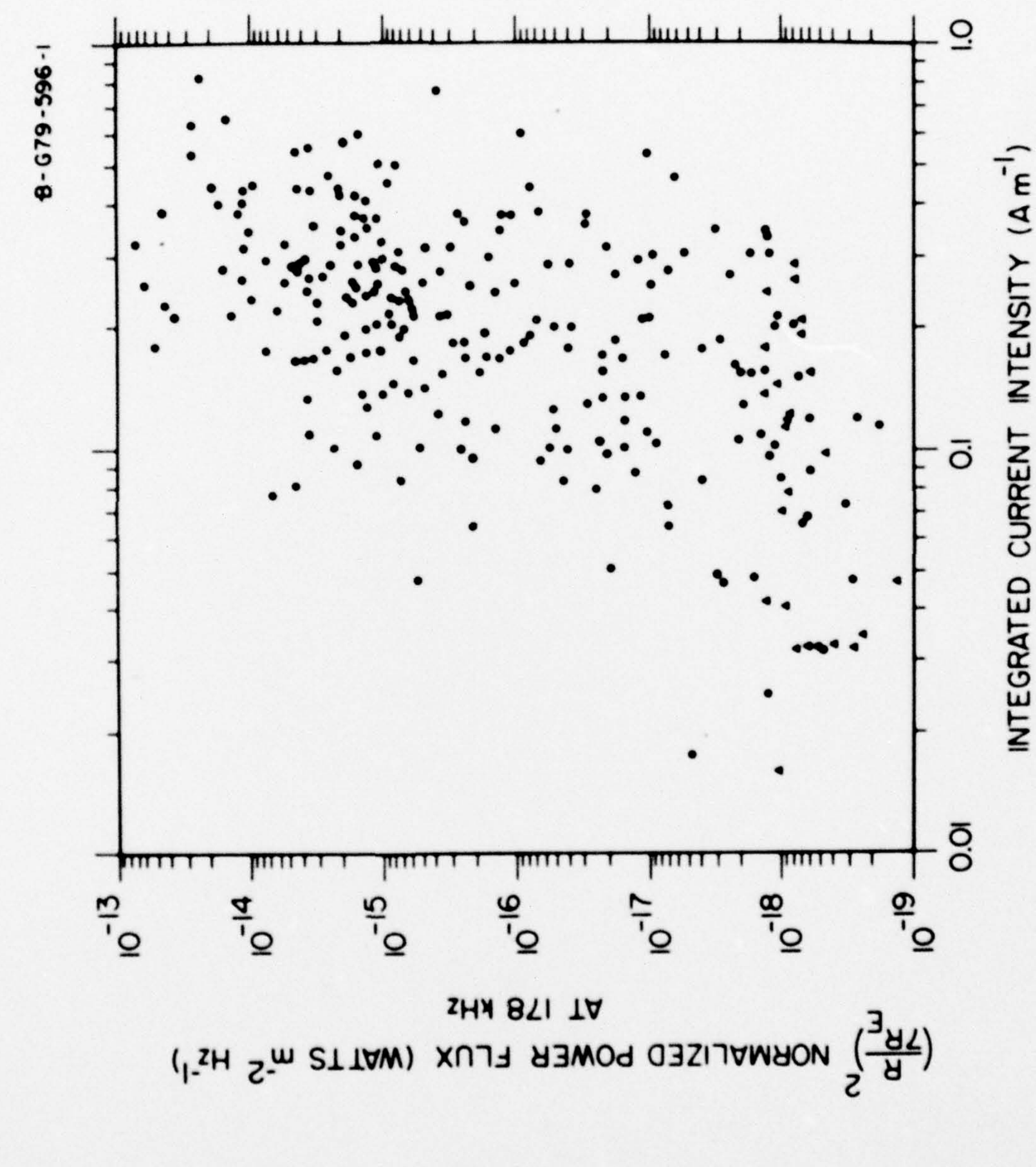

C-G78-812
JULY 23, 1974
A
B
C
D
POWER FLUX
(WATTS m^{-2} Hz^{-1})
FREQUENCY = 178 kHz
UT
MLAT
MLT
RE
0700 0800 0900 1000 1100 1200 1300 1400 1500
67.1 68.3 68.2 67.5 66.9 66.4 66.2 66.4 66.7
22.5 21.9 21.6 21.5 21.5 21.7 22.0 22.4 22.9
8.7 10.1 11.3 12.4 13.4 14.4 15.2 15.9 16.6
250 γ
ΔB
MLT ≈ 23.0
UT 0816 0818 0820 0822 0823
500 γ
UT 0955 0957 0959 1001 1003
UT 1135 1137 1139 1141 1143
UT 1316 1318 1320 1322 1324

Figure 3



B-G79-596-1
$\left(\frac{R}{7R_E}\right)^2$ NORMALIZED POWER FLUX (WATTS m^{-2} Hz^{-1}) AT 178 kHz
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-19}
0.01
0.1
1.0
INTEGRATED CURRENT INTENSITY (A m^{-1})

Figure 4